APPLICATION

of

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for

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on

SYSTEM FOR, AND METHOD OF, IRRADIATING OPPOSITE SIDES
OF ARTICLES WITH OPTIMAL AMOUNTS OF CUMULATIVE
IRRADIATION

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This invention relates to systems for, and methods of, irradiating articles, and particularly food articles, to sterilize the articles. The invention particularly relates to systems for, and methods of, irradiating opposite sides of the articles with cumulative irradiation between first and second intensities at all positions in the articles to sterilize the articles.

5   **BACKGROUND OF THE PREFERRED EMBODIMENTS**

It has been known for some time that drugs and medical instruments and implements have to be sterilized so that they will not cause patients to become ill from harmful bacteria when they are applied to the patients. Systems have accordingly been provided for sterilizing drugs and medical instruments and implements. The drugs and the medical instruments and

10   implements are then stored in sterilized packages until they are ready to be used.

In recent years, it has been discovered that foods can carry harmful bacteria if they are not processed properly or, even if they are processed properly, that the foods can harbor such harmful bacteria if they are not stored properly or retained under proper environmental conditions such as controlled temperatures. Some of these harmful bacteria can even be deadly.

15   For example, harmful bacteria have been discovered in recent years in hamburgers sold by one of the large national hamburger chains. Such harmful bacteria caused a number of

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purchasers of hamburgers from stores in the chain to become sick. As a result of this incident and several other similar incidents, it is now recommended that hamburgers should be cooked to a medium state rather than a medium rare or rare state.

5　Similarly, harmful bacteria have been found to exist in many chickens that are sold to the public. In view of a number of incidents which have occurred, it is now recommended that all chickens be cooked so that no blood is visible in the cooked chickens.

To prevent incidents such as discussed in the previous paragraphs from occurring, various industries have now started to plan on sterilizing foods before the foods are sold to the public. This is true, for example, of hamburgers and chickens. It is also true of fruits, particularly fruits 10 which are imported from foreign countries.

The food articles are generally irradiated from opposite sides of the articles. The cumulative amount of radiation at every position in the food articles should be at least a first magnitude to insure that all of the harmful bacteria in the articles are destroyed. The cumulative amount of radiation at every position in the articles should be less than a second magnitude to 15 insure that beneficial bacteria in the articles have not been destroyed . The second magnitude is greater than the first magnitude. The range of the cumulative radiation in the articles between the first and second magnitudes may be considered as optimal values of radiation.

The food articles may be provided with different thicknesses. It has been found that the cumulative amount of the radiation is different for different thicknesses of the food articles. For example, flat hamburger patties weighing one-half of a pound (½ lb.) have a different width or thickness in the flat plane than hamburger patties weighing a quarter of a pound (1/4 lb.).

5   Because of this, the cumulative amount of the radiation at various positions in the one-half pound hamburgers may be different from the cumulative amount of radiation at different positions in the one quarter pound (1/4 lb.) hamburgers.

For a first range of article thicknesses, the amount of the cumulative irradiation in the articles has been at the optimal values. For a second range of article thicknesses greater than the thicknesses in the first range, the cumulative amount of the radiation in the articles has been

10   found to be greater than the optimal value. For a third range of article thicknesses greater than the thicknesses in the second range, the cumulative amount of the irradiation at the different positions in the article has been found to again be at the optimal values.

As will be seen from the discussion in the previous paragraph, a problem exists when the

15   width or thickness of the food articles is in the second range since the cumulative amount of the irradiation at the different positions in the article is greater than the optimal values. The problem is compounded because the thicknesses in the second range are between the thicknesses in the first

and third ranges where the cumulative amount of irradiation at the different positions in the

articles is at the optimal values.

BRIEF DESCRIPTION OF THE PREFERRED EMBODIMENT

In a preferred embodiment of the invention, opposite sides of an article are irradiated to

5   sterilize the article. The cumulative irradiation should be above a first value, and below a second

value greater than the first value, at all of the positions in the article to provide the article with

desired radiation benefits. Any amount of cumulative radiation between the first and second

values is considered as optimal values.

For a first range of article thicknesses, the cumulative radiation in the article is at the

10   optimal values. For article thicknesses in a second range greater than the first range, the

cumulative radiation at positions in the article is greater than the optimal values. For article

thicknesses in a third range greater than the second range, the cumulative radiation at the

different positions in the article is at the optimal values.

For the thicknesses in the second range, a member disposed in the radiation path weakens

15   the radiation passing to the article, thereby reducing the cumulative radiation to an optimal value.

For each thickness in the second range, a different amount of cumulative radiation above the

optimal value may occur when the member is not disposed in the radiation path. The member

may accordingly be provided with different thicknesses, dependent upon the amount of the

cumulative radiation in the article for the different positions in the second thickness range, to

reduce the cumulative radiation in the article to an optimal value. A system operative

5   automatically positions the members properly for article thicknesses in the second range.

BRIEF DESCRIPTION OF THE PREFERRED DRAWINGS

In the drawings:

Figure 1 is a top plan of a system constituting a preferred embodiment of the invention

for irradiating opposite sides of articles, and particularly foods, with electron beams to sterilize

10   the articles;

Figure 2 is an elevational view of one of two (2) robotic assemblies included in the

preferred embodiment shown in Figure 1, one for transferring the articles form a loading area to a

first load conveyor and the other for transferring articles from a second load conveyor to an

unloading area;

15   Figure 3 is a top plan view of the robotic assembly shown in Figure 2;

Figure 4 is a top plan view of a process conveyor included in the preferred embodiment

of the system shown in Figures 1 - 3;

Figure 5 shows curves illustrating the intensity of the irradiation from opposite sides of

an article at progressive distances through the article and illustrating the cumulative intensity of

the radiation produced in the article at the progressive distances through the article;

Figure 6 shows curves illustrating the cumulative intensity of the irradiation at

5   progressive distances through the article when the distance between the opposite sides of the

article is varied;

Figure 7 is a chart showing the minimum and maximum irradiation intensities which are

to be produced in the articles at the different positions in the articles;

Figure 8 is a fragmentary plan view of apparatus which may be used in conjunction with

10   the system shown in Figures 1 - 4 for irradiating opposite sides of an article with a single

radiating source when the other of the two (2) radiation sources shown in Figure 1 becomes

inoperative;

Figure 9 is an enlarged perspective view of a plurality of articles stacked in a non-

uniform relationship on an article carrier movable on a transport mechanism toward the loading

15   area;

Figure 10 is an enlarged perspective view of a plurality of articles stacked in a uniform

relationship on an article carrier movable on the transport mechanism toward the loading area;

Figure 11 is a schematic top plan view of a system constituting another preferred

embodiment of the invention for irradiating opposite sides of an article, and particularly food,

20   with electron beams to sterilize the article;

Figure 12 is a drawing showing the relative amounts of irradiation produced in an article

for different thicknesses in the article when the article has progressive thicknesses;

Figure 13 is a schematic view of a system for irradiating an article with first and second

beams respectively disposed on opposite sides of the article and for disposing control members

5   between the beams and the article to maintain the irradiation within the article between optimal

limits when the article has a particular range of thicknesses;

Figure 14 is a schematic view of a system for irradiating opposite sides of an article with

a single beam and for disposing a control member between the beam and the article to maintain

the irradiation within the article between the optimal limits when the article has a particular range

10   of thicknesses;

Figure 15 is a schematic view of a system for automatically positioning the control

member between the radiation source and the article to maintain the irradiation in the article

within particular limits and shows the member in a non-operative position when the irradiation in

the article is within particular limits; and

15   Figure 16 is another schematic view of the automatic positioning system shown in Figure

15 and shows the disposition of the control member between the radiation source and the article

when the irradiation in the article would otherwise be outside of the particular limits.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

The preferred embodiments incorporate a number of the features disclosed in provisional

application 09/456,061 filed in the United States Patent and Trademark Office (USPTO) on

December 7, 1999, by John Thomas Allen, Gary K. Loda, Russell Parker, George M. Sullivan

5   and Colin Brian Williams for APPARATUS FOR, AND METHOD OF, STERILIZING

PRODUCTS, PRIMARILY FOOD PRODUCTS. The preferred embodiments also incorporate a

number of the features disclosed and claimed in U.S. patent 5,396,074 issued to Richard O. Peck,

Gary M. Pageau, Colin B. Williams, John T. Allen, Bernard G. Wickersham, Leonard C.

Bisgrove and Bruce D. Sellers on March 7, 1995, for an IRRADIATION SYSTEM UTILIZING

10   CONVEYOR-TRANSPORTED CARRIERS and assigned of record to the assignee of record of

this application. The preferred embodiments further incorporate features disclosed and claimed

in U.S. application 08/854,202 (docket TITAN-49534) filed on May 9, 1997, in the USPTO in

the names of John T. Allen, George M. Sullivan, Michael S. Brazell, Harold B. Knowles,

Anthony A. Zante, Richard J. Mendonsa, Richard C. Miller and Kenneth Whitman for ARTICLE

15   IRRADIATION SYSTEM IN WHICH ARTICLE-TRANSPORTING CONVEYOR IS

CLOSELY ENCOMPASSED BY SHIELDING MATERIAL and assigned of record to the

assignee of record of this application. In addition, the preferred embodiments incorporate

features disclosed and claimed in U.S. application 09/102,942 (docket TITAN-49641) filed in the

USPTO on June 23, 1998, for ARTICLE IRRADIATION SYSTEM HAVING

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INTERMEDIATE WALL OF RADIATION SHIELDING MATERIAL WITHIN LOOP OF

CONVEYOR SYSTEM THAT TRANSPORTS THE ARTICLES in the names of John T. Allen,

George M. Sullivan and Colin B. Williams as joint inventors and assigned of record to the

assignee of record of this application.   Reference may be made to patent 5,396,074 and/or to any

5   or all of the pending applications specified above to complete the disclosure in this application if

the disclosure in this application is found inadequate in any respect.

Figures 1-11 in this application respectively corresponds to Figures 1-11 in co-pending

application 09/456,061 specified above. The following description relating to Figures 1-11

respectively corresponds to the discussion relating to Figures 1-11 in co-pending application

10   09/450,061.

A preferred embodiment of a system of the invention is generally indicated at 10. The

system 10 includes a loading area, generally indicated at 12 (Figure 1), for receiving articles 14

which are disposed in a stacked relationship in article carriers 16. The articles may illustratively

be drugs, drug instruments and/or drug implements. The articles may also illustratively and

15   preferably be meats of various cuts such as hamburgers or may be chickens or fruits or juices or

any of a wide variety of other foods. The articles 14 may actually be anything which harbors

bacteria that are harmful to humans or animals and that will be destroyed when subjected to

irradiation by the system 10. In this way, the system 10 of this invention sterilizes the articles 14

for human or animal use or consumption.

The articles may be disposed in the article carriers 16 in a uniformly or non-uniformly

stacked relationship. A uniformly stacked relationship of the articles 14 in one of the article

5   carriers 16 is generally illustrated at 18 in Figure 10. A non-uniformly stacked relationship of

the articles 14 in another one of the article carriers 16 is illustrated at 20 in Figure 10.   It will be

appreciated that Figures 9 and 10 are only illustrative arrangements of the articles 14 in

uniformly non-stacked and uniformly stacked relationships.

The article carriers 16 are transported on a transport mechanism generally indicated at 22,

10   past the loading area 12. The direction of movement of the transport mechanism 22 is to the left

in Figure 1 as indicated by an arrow 24. The articles 14 are removed from the article carriers 16

by a robotic assembly 26, generally indicated at 26, which may constitute a Pallet Cell 100/200

apparatus manufactured and sold by FANUC Robotics North America, Inc.

The transfer of the articles 14 from the article carriers 16 by the robotic assembly 26 may

15   be controlled by a controller 28. The controller 28 is programmed to consider the disposition of

the individual ones of the articles 14 in the stacked relationship of the articles in the article

carriers 16 on the transport mechanism 22 and to operate the robotic assembly 26 in accordance

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with this stacked relationship whether the stacked relationship be uniform (Figure 10) or non-

uniform (Figure 9).

When the articles 14 are stacked in a uniform relationship (Figure 10) in the article

carriers 16, the controller 28 causes the robotic assembly 26 to move each of the successive

5   articles 14 in the article carriers 16 in the same path to a load conveyor 30 in the loading area 12

so that each of the articles will have a particular disposition on the loading conveyor. However,

when the articles 14 are stacked in the article carriers 16 in a non-uniform relationship (Figure 9),

the controller 28 causes the robotic assembly 26 to move in a path which is adjusted to take

account of the non-uniform relationship so that the articles will have the particular disposition on

10   the load conveyor 30.

The load conveyor 30 may transport the articles 14 at a selective speed such as

approximately sixty feet per minute (60'/min) to approximately ninety feet per minute (90'/min).

The speed of movement of the articles on the load conveyor 30 does not have to be regulated.

The load conveyor 30 may be divided into two (2) tracks 30a and 30b of substantially equal

15   widths as by a divider 32. Articles 14 may be simultaneously disposed on each of the tracks 30a

and 30b. The articles on each of the tracks 30a and 30b may be the same as, or different from,

the articles on the other one of the tracks.

The movement of the articles 14 on the tracks 30a and 30b may be provided by rollers 34 which may be driven by any suitable mechanism known in the art. At the position of transfer of the articles 14 to the load conveyor 30, the rollers 34 may have a herringbone configuration as indicated at 34a. In this configuration, separate rollers 34 may be disposed in each of the tracks

5   30a and 30b in an angled relationship to the rollers in the other track so that the end of the rollers adjacent the divider 32 is ahead of the end of the rollers distant from the divider in the direction of movement of the articles on the tracks.

In this way, the rollers 34 with the herringbone configuration 34a tend to displace the articles 14 from positions adjacent the divider 32 to positions displaced from the divider. This is

10   desirable to insure that the movement of the articles 14 on the load conveyor 30 will not be impeded by bumping against the divider 32. When the articles have been sufficiently displaced laterally from the divider 32, the rollers are preferably provided with a configuration 36 in which the rollers are substantially perpendicular to the divider 32 and are substantially parallel to one another.

15   The load conveyor 30 may be formed from a plurality of segments 36a, 36b, 36c, 36d, 36e, 36f and 36g, all of which are preferably disposed in a horizontal plane. The segments 36a, 36b, 36d and 36f may preferably constitute straight segments. The straight segments 36a, 36b and 36f may be disposed in a first direction and the straight segment 36d may be disposed in a

second direction substantially perpendicular to the segments 36a, 36b and 36f. The segments

36c, 36e and 36g may constitute curved segments each having a curvature of substantially 90⁰.

The curved segment 36c joins the straight segments 36b and 36d; the curved segment 36e joins

the straight segments 36d and 36f; and the curved segment 36g is contiguous to the straight

5   segment 36f.

A process conveyor generally indicated at 38 and having a horizontal disposition in the

same plane as the load conveyor 30 is contiguous at one end to the curved segment 36g of the

load conveyor 30. The process conveyor 38 is constructed to move the articles 30 at a particular

speed such as in the range of approximately thirty feet per minute (30'/min) to approximately

10   sixty feet per minute (60'/min). This speed is preferably regulated by the controller 38 so that it

is maintained within particular limits. If the speed should vary from these limits, the radiation

applied to the articles 14 on the process conveyor 38 may be interrupted and the operation of the

process conveyor may be discontinued.

The process conveyor 38 may be divided into two (2) tracks 38a and 38b, as by a divider

15   40, in a manner similar to the division of the load conveyor 30 into the two (2) tracks 30a and

30b by the divider 32. The process conveyor may be provided with rollers 42 having a

construction similar to the rollers 34 in the load conveyor 30. The rollers 42 at the end of the

process conveyor 38 adjacent to the load conveyor segment 36g has a herringbone configuration

42a. The herringbone configuration 42a of the rollers 42 differs form the herringbone

configuration 34a of the rollers 34 in that the ends of the rollers 42 distal from the divider 40 lead

the end of the rollers adjacent the divider in the direction of movement of the articles 14 on the

rollers. The rollers 42 accordingly operate to move the articles 14 on the tracks 38a and 36b to

5   positions contiguous to the divider 40.

The process conveyor is preferably divided into three (3) segments 39a, 39b and 39c

(Figure 4), in the direction of movement of the articles 14 on the tracks 38a and 38b, to form a

gap 44a between the segments 39a and 39b and to form a gap 44b between the segments 39b and

39c. The segments 39a, 39b and 39c may respectively and illustratively have lengths of

10   approximately three feet (3'), ten feet (10') and two feet (2'). The gaps 44a and 44 may

illustratively have lengths of approximately one half of one foot (½') in the direction of

movement of the articles 14 on the process conveyor 38. It will be appreciated that the articles

14 should preferably have a length greater than the lengths of the gaps 44a and 44b so that the

articles will be simultaneously on the segments 39a and 39b as they traverse the gap 44a and the

15   articles will be simultaneously on the segments 39b and 39c as they traverse the gap 44b.

A radiation source 46 (Figure 1) may be disposed to direct radiation through the gap 44a

to the articles 14 on the process conveyor 38. The radiation source 46 may be disposed in a

vertical direction above the process conveyor 38 to direct light downwardly on the articles 14 on

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the process conveyor. Similarly, a radiation source 48 may be disposed below the process

conveyor 38 to direct radiation upwardly through the gap 44b to the articles 14 on the process

conveyor 38. In this way, the radiation will be directed against the opposite sides of the articles

14 on the process conveyor 38. The intensities of the radiation from the sources 46 and 48

5   should preferably be substantially equal within particular limits.

The radiation sources 46 and 48 preferably provide an electron beam against the opposite

sides of the articles 14 on the process conveyor 38. Each of the radiation source 46 and 48

preferably provides an electron beam with an intensity of approximately ten (10) Mev. However,

the beam can be of any intensity to kill harmful bacteria in the articles 14 being irradiated

10   without killing beneficial bacteria in such articles. It will be appreciated that other types of

radiation sources than those providing electron beams may be satisfactory, particularly in special

situations. For example, gamma rays (as from cobalt or cesium) and X-rays may be satisfactory,

particularly in specific instances. However, electron beams are generally preferred since they

heat the articles only through a minimal range of temperatures and since the electrons directed

15   toward the beams are only temporary in duration. For example, the temperature increase of beef

patties when irradiated with an electron beam may be approximately 2^0F. This allows frozen

beef patties to remain frozen during and after the irradiation of the beef patties.

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Electron beam radiation has a number of advantages, particularly for irradiating food, in addition to those discussed in the previous paragraph. These additional advantages include high dose rate, the ability to turn the radiation sources instantaneously on and off, the ability to regulate the irradiated area as by beam scanning, no source replenishments, the ability to regulate

5   the strength of the radiation and the ability to operate in a dual mode (electron beam and X-ray). Other advantages of electron beam irradiation are relatively short exposure time, high power utilization in the fraction of the emitted energy usefully absorbed in the article being irradiated, simplified conveyor systems for the articles (e.g. the articles 14) because of the irradiation of individual articles rather than pallet-sized or tote-size loads and a minimization in the numbers

10   (only 1 or 2) of passes of the articles 14 through the target region of the radiation source(s).

There are certain definite advantages to converging the articles on the tracks 38a and 38b toward the divider 40 on the process conveyor before the articles 14 reach the radiation sources 46 and 48. By converging the articles 14 toward the divider 40, the widths of the radiation from each of the radiation sources 46 and 48 are minimized. This minimizes the consumption of

15   energy in the radiation sources 46 and 48. Alternatively, it provides for an increase in the energy directed by the radiation sources 46 and 48 against the articles 14 on the process conveyor 38.

As previously indicated, the speed of movement of the articles 14 on the load conveyor 30 is preferably greater than the speed of movement of the articles on the process conveyor 38.

If the proper ratio of speeds is selected (depending on the lengths of the articles 14), the spacing

between successive articles on the process conveyor is minimized, thereby increasing the

efficiency in the operation of the system and decreasing the amount of power not utilized.

    The articles 14 on the process conveyor 38 are transferred to a load conveyor generally

5   indicated at 50 (Figure 1). The load conveyor 50 may have a construction similar to that of the

load conveyor 30. For example, a divider 52 may be provided to divide the load conveyor 50

into two (2) tracks 50a and 50b and rollers 54 may be provided on the load conveyor to advance

the articles 14 on the load conveyor toward an unloading station generally indicated at 56. The

rollers 54 adjacent the process conveyor 38 may be provided with a herringbone configuration

10   54a similar to the herringbone configuration 34a of the rollers 34. This facilitates the movement

of the articles on the load conveyor 50. The resultant separation of the articles 14 on each of the

tracks 50a and 50b at the unloading station 56 facilitates the separate and individual handling of

the articles at the unloading station.

    The load conveyor 50 may be formed from several segments 58a, 58b, 58c, 58d, 58e, 58f,

15   58g and 58h. The segment 58a is contiguous to the process conveyor 30 and is curved. The

segment 58b is contiguous to the segment 58c and is also curved. However, the segments 58a

and 58b have opposite curvatures so that the articles 14 passing from the segment 58b travel in

an opposite direction through the segment 58c relative to the direction in which the articles pass

from the process conveyor 38 to the segment 58a. The segment 58c is a straight segment parallel

to the process conveyor 38. The segments 58d and 58e cumulatively provide a curvature of 180^0

in a manner corresponding to the segments 58a and 58b. The segment 58f is straight and is

parallel to the segment 58c but extends in a direction opposite to the direction of the segment

5   58c. The segment 58g provides a curvature of 90^0 between the segments 58f and 58h. The

segment 58h extends in a direction parallel, but opposite, to the segment 36a in the load

conveyor 30. The segment 58h extends to the unloading area 56.

A robotic assembly generally indicated at 60 may be disposed in the unloading area 56 to

receive the articles 14 from the load conveyor 50 and to transfer the articles to the article carriers

10   16 on the transport mechanism 22. The article carriers 16 may constitute those from which the

articles 14 have been previously transferred to the load conveyor 30 in the loading area 12.

Because of this, the article carriers 16 adjacent to the unloading area 56 are empty. The articles

14 may be transferred to the load conveyor 50 in the unloading area 56 in a uniform relationship

such as indicated at 18 in Figure 10 or in any other uniform relationship or in a non-uniform

15   relationship such as indicated at 20 in Figure 9 or in any other non-uniform relationship. The

transfer of the articles 14 from the load conveyor 50 to the article carriers 16 on the transport

mechanism 22 in the uniform or non-uniform relationship may be under the control of the

controller 28. The robotic assembly 60 in the unloading area 56 may correspond in construction

to the robotic assembly 26 in the loading area 12.

The robotic assembly 26 includes a platform 62 (Figures 3 and 4) which is rotatable in a

horizontal plane through an annulus indicated at 64 in Figure 4. A support member 66 extends

upwardly from the platform 64. An arm 68 is pivotable in a vertical plane on a pin 70 as a

fulcrum, the pin being disposed on the support member 66. A strut 72 supported on the arm 68 is

5   pivotable in a vertical plane on a pin 74. A plate 76 is supported by the strut 70 for a rotary

movement in a horizontal plane through an annulus indicated at 78 in Figure 4.

The platform 62 rotates in the horizontal plane to a position for disposition of the arm 68

in contiguous relationship to one of the articles 14 in one of the article carriers 16 on the

transport mechanism 22. The arm 68 is then pivoted on the pin 70 as a fulcrum to provide for the

10   plate 74 to lift the article 14 from the article carrier 16. The platform 62 is then rotated through a

horizontal plane to the position of the load conveyor 30. The plate 76 is thereafter rotated to the

position for depositing the article 14 in a properly aligned relationship on the load conveyor 30.

The strut 72 is then pivoted downwardly on the pivot pin 74 as a fulcrum to deposit the article in

the properly aligned relationship on the load conveyor 30.

15   The inclusion of the two (2) tracks in each of the load conveyor 30, the process conveyor

38 and the load conveyor 50 provides certain important advantages. It allows the articles 14 to

be moved past the radiation sources 46 and 48 at one half (½) of the speed at which the articles

14 would move if only one (1) track were provided. A reduced speed is desirable because it

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simplifies the operation of the irradiating system 10. Another advantage of providing the two (2)

tracks in each of the load conveyor 30, the process conveyor 38 and the load conveyor 50 is that

one type of article 14 can be processed on one of the tracks at the same time that another type of

article can be processed on the other track.

5   The inclusion of the radiation sources 46 and 48 to apply radiation respectively from

positions above and below the articles 14 also provides certain important advantages. One

advantage is that the use of the radiation sources 46 and 48 minimizes the time for processing the

articles 14. Another advantage is that the thickness of the article 14 being sterilized in each pass

can be increased without increasing the intensity of the radiation from the sources 46 and 48.

10   A further advantage is that the article 14 does not have to be inverted in order to apply

radiation to the second opposite side of the article 14. Inverting the article 14 is undesirable

when products such as fresh meat patties are being pasteurized. This results from the fact that

blood from what was originally the bottom side of the article 14 flows to what was originally the

top side of the article when the article is inverted. This blood discolors the visual appearance of

15   the article 14 when the article is again inverted so that what was originally the top side of the

article again becomes the top side of the article.

Radiation shielding generally indicated at 78 in Figure 1 may be applied to the system 10

(a) to limit the existence of radiation from the radiation sources 46 and 48 in areas other than the

target region where the articles 14 are to be irradiated and (b) to prevent radiation from the

sources from reaching the loading area 12 and the unloading area 56. The radiation shielding 78

5   may be formed from a suitable material such as concrete. The radiation shielding 78 may

encompass the system 10 and may include (a) a portion 80a adjacent the load conveyor segment

36b, (b) a portion 80b adjacent the load conveyor segments 36c, 36d and 36e, (c) a portion 80c

adjacent the load conveyor segments 36e, 36f and 36g, (d) a portion 80d adjacent the load

conveyor segment 36g, the process conveyor 38 and the load conveyor segment 58a, and (e) a

10   portion 80e adjacent the load conveyor segments 58a, 58b, 58g and 58h. The radiation shielding

segments 80a - 80e are integral or continuous with one another. A radiation shielding portion

80f integral with the radiation shielding portions 80a - 80e extends into the space between the

load conveyor segments 58c and 58f.

A radiation shielding member 82 made from a suitable material such as concrete and

15   separated from the radiation shielding portions 80a - 80f is disposed in the region between the

process conveyor 38 and the load conveyor segment 58c. The radiation shielding member 82

limits the amount of radiation passing to the radiation shielding portions 80a - 80c and 88e and

accordingly provides for a decrease in the thickness of these radiation shielding portions. The

radiation shielding portions 80a - 80f and the radiation shielding member 82 are preferably

integral with a floor (not shown) made from a suitable material such as concrete and a roof (not

shown) made from a suitable radiation shielding material such as concrete. In this way, the

system 10 is disposed within an enclosure made from a radiation shielding material such as

concrete.

5   As previously described, the articles 14 may travel on the two tracks 30a and 30b of the

load conveyor 30 from the loading area 12, then on the two (2) tracks 38 and 38b of the process

conveyor 38 and then on the two (2) tracks 50a and 50b of the load conveyor 50 to the unloading

area 56. During the movement of the articles 14 on the process conveyor 38, each of the

radiation sources 46 and 48 irradiates the articles 14 on the two tracks 38 and 38b. However, it

10   may sometimes happen that one of the radiation sources 46 and 48 may be inoperative to

irradiate the articles 14 on the tracks 38a and 38b of the process conveyor 38. Assume that it is

the radiation source 46. Under such circumstances, the other one of the radiation sources 46 and

48 (assume that it is the source 48) performs a double duty and irradiates the two (2) opposite

sides of the articles 14 on the tracks 38a and 38b of the process conveyor 38.

15   To provide for the radiation source 48 to irradiate the two (2) opposite sides of the articles

14, an alternative load conveyor (one track wide), generally indicated at 84 in Figure 8, is

provided between the first track 50a of the load conveyor 50 and the second track 30b of the load

conveyor 30. The path of travel of the articles 14 is then the first track 30a of the load conveyor

30, the first track 38a of the process conveyor 38 and the first track 50a of the load conveyor 50. During this path of travel , the first side of the articles 14 is irradiated by the radiation source 48.

The articles 14 then travel from the first track 50a of the load conveyor 50 through the alternate load conveyor 84 (one track wide) to the second track 30b of the load conveyor 30.

5   During this travel, the articles 14 reach a barrier 86. To surmount this barrier, a lifting mechanism 88 is provided to lift the articles from the side of the barrier 86 adjacent the load conveyor 50 to the side of the barrier adjacent the load conveyor 30. While the articles 14 are being lifted above the barrier 86, they are inverted. The articles 14 then travel from the second track 30b of the load conveyor 30 to the second track 38b of the process conveyor 38, then to the

10   second track 50h of the load conveyor 50 and then to the unloading area 56. The radiation source 48 irradiates the second opposite side of the articles 14 during this second movement of the articles 14 past the radiation source 48. The same paths as described above in this paragraph and the previous paragraph are provided when the radiation 48 is unable to irradiate the articles 14 and the radiation source 46 irradiates the two (2) opposite sides of the articles.

15   A curve 90 in Figure 5 shows the irradiation intensity produced in the article 14 at different depths in the article when radiation is provided from the source 46 downwardly on the article. As will be seen, the irradiation intensity increases for some distance downwardly from the top of the article 14 until it reaches a maximum value and then the irradiation dose decreases

from that maximum value with further progressive distances downwardly through the article.

Figure 5 also shows an irradiation intensity 92 produced in the article 14 by the source 48. As

will be seen, the irradiation intensity from the source 48 increases for a particular distance

upwardly through the article 14 from the bottom of the article to a maximum value and then

5   decreases from that maximum value with further progressive distances upwardly through the

article. The curve 92 may be considered as an inverse of the curve 90.

A curve 94 in Figure 9 constitutes a composite of the curves 90 and 92. The composite

curve 94 in Figure 9 has a radiation intensity 96 at the top of the article 14. This corresponds

substantially to the radiation intensity at the top of the article 14 for the curve 90. The intensity

10   of the radiation in the composite curve 94 then increases from the dose 96 to a maximum value

98 at a position approximating in the article 14 the position at which the curve 90 has an

irradiation intensity corresponding to the irradiation intensity in the curve 92.

Figure 6 illustrates composite curves for progressive increases in the thickness of the

article 14. The composite curve 94 in Figure 5 is repeated in Figure 6. A curve 100 in Figure 10

15   constitutes a composite of the radiation intensities produced by the sources 46 and 48 when the

thickness of the article 14 is increased by a first amount from the thickness of the article in the

composite curve 94. A curve 102 constitutes a composite of the radiation intensities produced by

the radiation sources 46 and 48 when the thickness of the article 14 is increased by a second

amount greater than the first amount from the thickness of the article 14 for the composite curve 94. As will be seen for each of the composite curves 100 and 102, the difference between the maximum and minimum radiation intensities increases as the thickness of the article 14 increases above the thickness of the article for the composite curve 94.

5   Figure 7 is a chart showing the range of irradiation intensities that the system described above should produce. For example, the irradiation system 10 should produce at least a first irradiation dose 110 in Figure 7 at every position in the article 14 in order to reduce the number of harmful organisms such as E-Coli, listeria and salmonella when the article is a beef patty. If the irradiation intensity at any position in the article 14 is below the value 110, the harmful

10   organisms (e.g. E-Coli) in the article may not be reduced sufficiently so that a person eating the beef patty can become sick. The radiation intensity should not exceed a second value 112 at every position in the article in order to preserve the life of beneficial organisms in such articles 14 as beef patties. As will be seen, the radiation intensity 112 is greater than the radiation intensity 110.

15   As will be seen, the difference between the maximum radiation intensity 112 and the minimum radiation intensity 110 at different vertical positions in the article 14 increases with increases in the thickness of the article. It is desirable to maintain this difference within particular limits. On the other hand, it is desirable to maintain the ability of the system 10 to

process as thick articles 14 as possible in order to maintain the versatility of the system. Success

is accordingly achieved by providing an optimum thickness of the articles 14 at an optimum ratio

of the maximum value 112 and the minimum value 110 of the radiation dose throughout the

article and by providing these parameters at the lowest cost.

5   Figure 11 illustrates another preferred embodiment, generally indicated at 200, of a

system constituting the invention. However, the system 200 is not as preferred as the system 10.

The preferred embodiment 200 shown in Figure 11 includes a pair of radiation sources 202 and

204 respectively corresponding to the radiation sources 46 and 48 in the embodiment shown in

Figures 1 - 4 and described above. The system 200 includes a load conveyor, generally indicated

10   at 208, having a straight portion 208a extending from a loading area 206, a portion 208b having a

curvature of substantially 90^0, a straight portion 208c extending in a direction opposite to the

straight portion 208a, a portion 208d having a curvature of substantially 90^0 and extending in a

direction opposite to the curved portion 208b, a straight portion 208e extending in a direction

corresponding to the straight portion 208a, a portion 208f having a curvature of substantially 90^0,

15   a straight portion 208g extending in the same direction as the straight portion 208c and a portion

208h having a curvature of substantially 90^0.

A process conveyor generally indicated at 209 extends from the load conveyor portion

208h in a straight path having a direction corresponding to the load conveyor portion 208a. The

radiation sources 202 and 204 are disposed at gaps in the process conveyor 209. A load

conveyor generally indicated at 211 extends from the process conveyor 209. The load conveyor

211 has a curved portion 211a, a straight portion 211b, a curved portion 211c, a straight portion

211d, a curved portion 211e, a straight portion 211f, a curved portion 211g and straight portions

5   211h and 211i. A curved portion may be disposed between the straight portions 211h and 211i.

An unloading area 213 may be disposed at the end of the straight portion 211i.

Radiation shielding material, generally indicated at 210, such as concrete envelopes the

system 200 to define a chamber. Radiation shielding material 212 such as concrete is disposed

within the loop defined by the process conveyor 209, the load conveyor portions 208e - 208h and

10   the load conveyor portions 211a - 211e to define a wall. A wall 214 made from the radiation

shielding material such as concrete extends integrally from the radiation shielding material 212

into the space between the curved portions 208d and 211e. A roof and a floor made from a

radiation shielding material such as concrete may also be provided in the embodiment shown in

Figure 11.

15   The embodiment shown in Figure 11 appears to have certain disadvantages relative to the

embodiment shown in Figures 1 - 4 and described above. It appears to occupy more space than

the embodiment shown in Figures 1 - 4. It also appears to require more radiation shielding

material than the embodiment shown in Figures 1 - 4. Furthermore, the loading and unloading

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areas in the embodiment shown in Figure 11 appear to be significantly removed from each other

relative to the positioning of the loading area 12 and the unloading area 56 in the embodiment

shown in Figures 1 - 4. This increases the difficulty of transferring the articles 14 between the

loading 206 and the unloading area 213 in the embodiment shown in Figure 11. In view of the

5   above, the embodiment shown in Figures 1 - 4 and described above appears to be the preferred

embodiment in comparison to the embodiment 200 in Figure 11.

Figure 12 is a curve, generally indicated at 300, showing on a horizontal axis the

thickness in inches of the article 14 (with unit density) being irradiated. The curve 300 also

10   shows on a vertical axis a ratio between the minimum amount of the cumulative radiation at any

position in the article 14 and the maximum amount of the cumulative radiation at any position in

the article.

A broken line 302 is provided in Figure 12 to indicate the lowest level at which the

cumulative amount of radiation can be provided in the article 14 to kill all of the harmful bacteria

15   in the article. A broken line 304 is provided in Figure 12 to indicate the highest level at which

the cumulative amount of the radiation can be provided in the article 14 without harming the

beneficial bacteria in the article. The area in Figure 12 between the broken lines 302 and 304

constitutes the optimal values for the production of the cumulative amount of irradiation in the

article 14 at different thicknesses in the article.

The curve 300 represents empirical data. The curve 300 includes a first portion 306

which extends from a zero (0) thickness to a thickness 308 at which the first portion crosses the

broken line 304 to a position above the broken line. This occurs at a thickness of approximately

one and five eighth inches (1-5/8"). As will be seen in Figure 12, the first portion 306 is within

5   the area which constitutes the optimal values for the production of the cumulative amount of the

irradiation in the article at the different positions in the article.

The curve 300 includes a second portion 310. The portion 310 extends from the article

thickness 308 to an article thickness 312 at which the second portion crosses the broken line 304

into the optimal area between the broken lines 302 and 304. This occurs at a thickness of

10   approximately three inches (3"). As will be seen, the second portion 310 provides at each

different thickness a cumulative amount of irradiation which is greater than that represented by

the broken line 304. This indicates that the cumulative amount of the irradiation is at the level

where beneficial bacteria in the article will be destroyed.

The curve 300 includes a third portion 314 which extends from the article thickness 312

15   to an article thickness 316 at which the third portion intersects the broken line 304 and extends

above the broken line 304. This occurs at a thickness of approximately three and three eighths

inches (3-3/8"). The third portion 314 is within the area which constitutes the optimal value for

the production of the cumulative amount of the irradiation in the article.

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As will be seen in Figure 12, it would be desirable to reduce the cumulative amount of

the irradiation in the curve portion 310 to a value within the optimal area defined by the broken

lines 302 and 304. Preferably this can be accomplished by disposing members 320 and 322

(Figure 13) respectively between the radiation sources 46 and 48 and the article 14 on the process

5   conveyor 38 in the embodiment shown in Figures 1-4. The members 320 and 322 may be made

from a suitable material such as a metal. The metal may illustratively be aluminum or copper.

The members 320 and 322 may be provided with substantially identical characteristics.

The members 320 and 322 may be considered as attenuators which reduce the level of the

cumulative amount of the irradiation in the article 14 to a magnitude between the broken lines

10   302 and 304 in Figure 12. Preferably the members 302 and 304 reduce the cumulative amount of

the irradiation in the article 14 to a level indicated at 324 in Figure 12. This level is desirable

because it is further from the broken line 304 than any other thickness in the third portion 314.

Figure 14 is a schematic showing similar to the schematic showing in Figure 13 except

that it employs only the member 320 for attenuating the irradiation in the article 14 to the optimal

15   value between the broken lines 302 and 304. This results from the displacement of the member

322 to a position to one side of the beam between the source 48 and the article 14 as shown in

Figure 14. The system shown in Figure 13 and 14 is used in conjunction with the system shown

in Figures 8-11 to attenuate the irradiation in the article 14 to the optimal value between the

broken lines 302 and 304 when the thickness of the article 14 is between the positions 308 and

312 in Figure 12.

A system generally indicated at 330 in Figures 15 and 16 may be provided for

automatically moving the member 320 to a thickness for obtaining the optimal level of the

5   cumulative amount of the irradiation in the article 14 when the thickness of the article 14 is in the

second portion 310 of the curve 300. In this system, the member 320 is provided with a

particular thickness at progressive incremental positions. The thickness of the member at these

particular thicknesses corresponds to the distance of the second portion 310 of the curve 300

above the broken lines 304 at progressive incremental thicknesses along the second portion 310.

10   Each of the progressive incremental positions in the members 320 and 322 may be preferably

provided with a width corresponding to the width of the radiation beam from the source 46. This

width is indicated at 331 in Figure 15.

A microprocessor 332 in the system 330 receives information relating to the thickness of

the article 14 when the article has a thickness in the second portion 310 of the curve 300. The

15   microprocessor causes the member 320 to move to the incremental position between the source

46 and the article 14 through a distance related to the distance between the beginning 308 of the

second portion 310 and the thickness of the article in the second portion 310. For example, the

microprocessor 332 may cause the member 320 to move through an incremental distance related

to the distance between the beginning 308 of the second portion 310 and a position 333 in Figure

12 when the article has the thickness or width 335. At this distance, the member 320 may have a

thickness to compensate for the amount at the thickness position 333 of the cumulative

irradiation above the optimal level 324 of the cumulative irradiation in the third portion 314.

5   The movement of the member 320 is provided by a pinion gear 334 which rotates in

response to commands from the microprocessor 332 to move a rack gear 336 formed at the

bottom of the member 320. In this way, the optimal level 324 of the cumulative amount of the

irradiation is maintained regardless of the thickness of the article 14 in the second portion 310 of

the curve 300.

10   It will be appreciated to a person of ordinary skill in the art from Figures 15 and 16 and

from the discussion above that the embodiment shown in Figures 15 and 16 can be modified and

used in the modified form with the embodiment shown in Figures 1-4 to provide the automatic

movement of the members 320 and 322 to a desired position. In this desired position, the

members 320 and 322 are positioned in the path of the beams from the radiation sources 46 and

15   48 to the article 14 to reduce the cumulative radiation in the article to an intensity between the

broken lines 302 and 304 when the intensity of the radiation would otherwise be above the

broken line 304.

Although this invention has been disclosed and illustrated with reference to particular preferred embodiments, the principles involved are susceptible for use in numerous other embodiments which will be apparent to persons of ordinary skill in the art. The invention is, therefore, to be limited only as indicated by the scope of the appended claims.

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